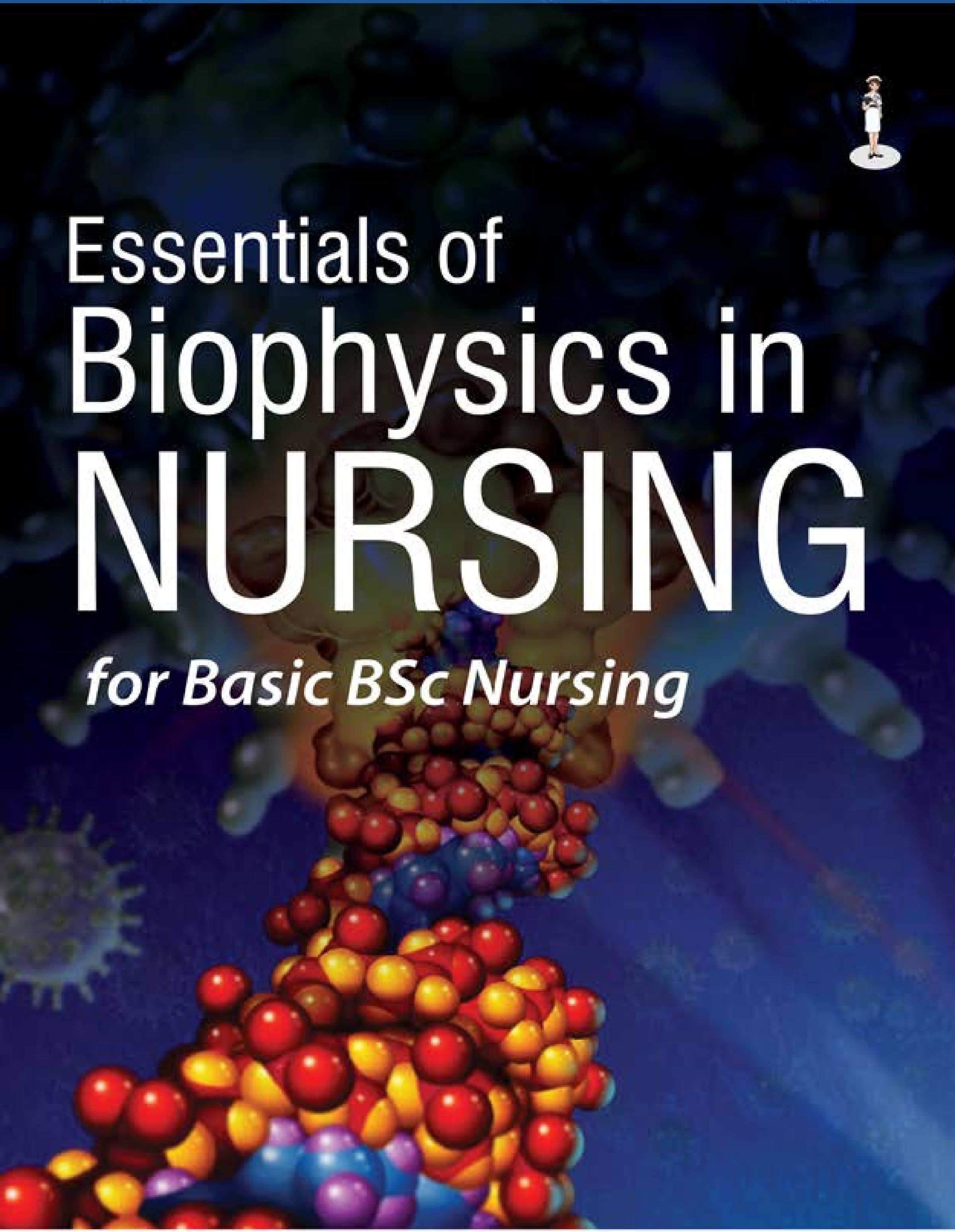

Essentials of Biophysics in NURSING

for Basic BSc Nursing

Nisha Clement

JAYPEE

Contents

CHAPTER

3

Motion

INTRODUCTION

In our everyday life, we observe that some effort is required to put a stationary object into motion or to stop a moving object. Normally we have to push or pull or hit an object to change its state of motion. The concept of force is based on this push, pull or hit. No one has seen, tasted, or felt force. However, we always see or feel the effect of a force. It can only be explained by describing what happens when a force is applied to an object. Push, pull or hit may bring objects into motion, because we make a force to act on them. Therefore, force is one which changes or tends to change the state of rest or of uniform motion of a body. Force is a vector quantity. Its SI unit is newton.

MEANING OF MOTION

Every object in the universe is in motion. Every day we see bodies moving around us, e.g. birds flying, cars and buses moving, people walking, insect crawling, animals running, etc. our earth also moves around the sun. We often say that a stone lying on the ground is at rest. But, indeed the stone is also moving along with the earth around the sun. The sun and stars also moving.

Any physical quantity which can be measured on some scale is said to be a scalar quantity. Any scalar quantity has a magnitude. For example, if the distance covered by a moving body is 5 m, those 5 m is the magnitude of the distance. Any physical quantity which has magnitude as well as direction is called vector quantity. Speed is the rate change of motion and its units are cm/s in CGS system and m/s in SI system.

MECHANICS OF MOTION

Motion is a common phenomenon for the objects in the universe. Galileo told that motion can be described in the terms of (a) Two fundamental physical quantities, i.e. length or spacing and duration or time (b) Two derived physical quantities, i.e. velocity and acceleration. Rest and motion are two interrelated states. Study of motion may be done by not bothering for the cause of motion. A motion is generally described by selecting the starting instant of time as origin. The simplest form of motion of the body is the motion in a straight line. Motion is a branch of physics which deals with the study of rest and motion of bodies in the universe. It has further two major branches: statics and dynamics.

1. **Statics:** It is a branch of mechanics which deals with the study of the conditions of a body at rest.
2. **Dynamics:** It is a branch of mechanics which deals with the study of motion of objects taking into account the cause of motion.
3. **Kinematics:** It is a branch of mechanics which deals with the study of motion of objects without taking into account the cause of motion.

TYPES OF MOTION

Physics recognizes three forms of motion. Uniform motion refers to location changes at a constant speed. For example, a train traveling from station A to station B at a constant speed of 50 mph. Accelerated motion refers to location changes that involve acceleration. For example, when an apple falls from a tree, it accelerates due to the force of gravity. Random motion refers to changes in location that are random, unexpected or unpredictable. An example of random motion is the movement of sub-atomic particles. Motion is change of position of a body in particular time with reference to a stationary body. The types of motion are:

1. **Translatory motion:** Motion occurring in one direction. The 2 types are:
   a. **Rectilinear motion:** Motion of a body in a straight line, e.g. a car moving on the road, a coconut falling down from the tree, a child moving down in a slide.
   b. **Curvilinear translatory motion:** Motion of a body along a curved path, e.g. a man running in a 400 m. Race along the circular path.
2. **Circular motion:** Motion of a body in a circle around the fixed point in the center.
   a. **Rotatory motion:** Part of the body occupies a particular position at a time. For example, rotation of the earth on its axis, rotation of the blades of a fan, movement of the hands of a clock.
   b. **Revolution:** Motion of the whole body in a circle around a central fixed point. For example, movement of the earth around the sun.
3. **Oscillatory motion:** The 'to and fro' motion of a body, e.g. motion of a swing, movement of the 'bob' of a pendulum in a clock, the motion of a bell attached to a long chain.
4. **Periodic motion:** The bodies occupy a particular position at regular intervals. For example, position of minute hand in a clock once in every 60 minutes. Hour hand in a clock once in every 12 hours, position of planets in their orbits around the sun. Nonperiodic motion-vibratory motion of the drum.
5. **Random motion:** Motion of a body on any direction, e.g. motion of butterflies and honey bees around the flowers, movement of football players in the field.

NEWTON'S LAWS OF MOTION

Galileo observed the motion of objects on an inclined plane. He deduced that objects move with a constant speed when no force acts on them. Newton studied Galileo's ideas on force and motion and presented three fundamental laws that govern the motion of objects. These three laws are known as **Newton's Laws of Motion:** The first law of motion is stated as: An object remains in the state of rest or of uniform motion in a straight line unless compelled to change that state by an applied unbalanced force. In other words, all objects resist a change in their state of motion. The tendency of undisturbed objects to stay at rest or to keep moving with the same velocity is called inertia. This is why, the first law of motion is also known as the law of inertia. Motion of bodies is governed by three fundamental laws called Newton's laws of motion. Sir Isaac Newton studied the motion of bodies and formulated these laws. (Apart from this, Newton has also worked in the fields of optics and thermodynamics. He was also a famous mathematician who has invented the calculus and the binomial theorem.

Newton's first law (law of inertia): Everybody tries to preserve its state of rest or of uniform motion along a straight line unless acted by an external agency, called force. Force is defined as that external agency which changes the state of rest or of uniform motion of a body. Inertia is the property by virtue of which a body tends to retain its position of rest or of uniform motion in a straight line. The force is that which overcomes inertia. A common example of this law is that when a bus moving with uniform speed suddenly stops, the passengers tend to fall forward. When the bus is moving, the passengers are also in a state of uniform motion and tend to continue in the same state even after the bus stops and hence they fall forward. If the bus suddenly starts from rest, the passengers fall backwards.

Newton's second law: The acceleration of a body is directly proportional to the net force acting upon it and inversely proportional to its mass.

The second law gives an expression for the measurement of force.

$$a \propto \frac{F}{m} \quad \text{or} \quad F \propto ma$$

The proportionality symbol can be converted into equality by multiplying the right hand side by a constant called proportionality constant. Therefore, the above expression becomes,

$$F = Kma$$

The value of 'K' varies depending on the system chosen for measurement.

In SI, the value of 'K' is 1. Hence

$$F = ma$$

Force is measured by a unit called newton 'N' in SI system. Since acceleration is a vector quantity force is also a vector quantity.

Momentum

The product of mass 'm' and velocity 'v' of a body is called its momentum 'P'. It is also a vector quantity. The unit of momentum in SI is N-s.

The concept of momentum is very useful in calculating the distance of penetration of a bullet inside an object, in calculating the recoil velocity of a rifle and in various other circumstances. Newton's second law can be stated in another form in terms of momentum. It states that the rate of change of momentum is proportional to the impressed force and takes place in the direction of the force.

Newton's third law: It states that for every action there is an equal and opposite reaction. There are numerous examples to illustrate Newton's third law. The launching of rockets is based on this principle. The exhaust gases ejected downwards from the bottom pushes up the rocket.

A bullet shot from a gun pushes the gun backwards while moving forwards. Here, the movement of the bullet in one direction can be considered as the action and the recoil of the gun as the reaction or vice versa. The motion of a boat in a river in one direction is the result of the movement of water in the opposite direction.

Law of Conservation of Momentum

When there is no external force acting on a system, its total momentum remains constant. This law follows from Newton's second law of motion. When the force on a system is zero, the rate of change of momentum is zero which implies that the total momentum of the system remains constant.

Uniform circular motion: Motion of a body in a circular path with constant 'peed and constant radius is called uniform circular motion. Though speed remains constant, velocity and acceleration change continuously since the direction of motion changes continuously.

Due to continuously changing acceleration, a force acts on the body. The acceleration can be considered in two parts called rectangular components.

These components are mutually perpendicular to each other. One component is directed towards the center of the orbit and it is called centripetal or radial (center-seeking) acceleration. The other component is called tangential (or transverse) acceleration.

Centripetal Acceleration and Centripetal Force

The centripetal acceleration of a body in uniform circular motion is always directed towards the center and is a constant.

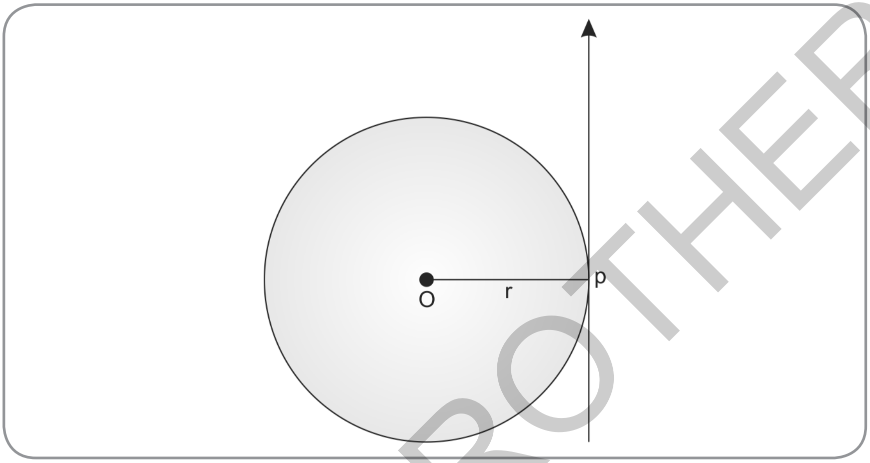

Fig. 3.1: Centripetal acceleration and centripetal force

'O' is the center of a circular path of radius 'r' and 'v' is the velocity of the moving particle at the point. The centripetal acceleration of the particle is given by

$$a = \frac{v^2}{r}$$

The linear velocity is that velocity with which a body in uniform circular motion would move when it is cut off from its circular path.

Centripetal force is defined as the force exerted on the body in circular motion towards the center of the circular path. This force changes the direction of motion continuously. By the definition of force given in Newton's second law, the expression for centripetal force can be written as

$$F = \frac{mv^2}{r}$$

VECTOR

Vector is a physical quantity that requires the specification of both magnitude and direction. Examples of vector are: weight, displacement, velocity, acceleration, momentum, force, etc. A vector is a geometric entity characterized by a magnitude (in mathematics a number, in physics a number times a unit) and a direction. In rigorous mathematical treatments, a vector is defined as a directed line segment, or arrow, in a Euclidean space. When it becomes necessary to distinguish it from vectors as defined elsewhere, this is sometimes referred to as a **geometric**, **spatial**, or **Euclidean** vector.

Definition

1. Vector defined as a directed line segment in space representing some physical quantity both in magnitude and direction.
2. Vectors are defined as quantities that include both magnitude and direction. That means that completely specifying a vector quantity requires two numbers, one for the magnitude, or amount, and another for the direction.

As an arrow in Euclidean space, a vector possesses a definite initial point and terminal point. Such a vector is called a **bound vector**. When only the magnitude and direction of the vector matter, then the particular initial point is of no importance, and the vector is called a **free vector**. Thus two arrows $\overrightarrow{AB}$ and $\overrightarrow{A'B'}$ in space represent the same free vector if they have the same magnitude and direction: That is, they are equivalent if the quadrilateral *ABB'A'* is a parallelogram. If the Euclidean space is equipped with a choice of origin, then a free vector is equivalent to the bound vector of the same magnitude and direction whose initial point is the origin.

The term vector also has generalizations to higher dimensions and to more formal approaches with much wider applications.

Concept of vector: Consider a wind weather report. One can report the wind speed by saying it is 20 miles per hour. Here the reported speed is not a vector quantity. It is a scalar. However just reporting the wind speed does not give all the information about the wind. Someone wanting to go sailing will also want to know the wind direction. In this case, direction matters. A more complete wind velocity report might say that the wind is blowing 20 miles per hour towards the southwest. This wind velocity includes both the magnitude (20 miles per hour) and the direction (towards the southwest), so it is a vector quantity. (Parenthetical note: a wind blowing towards the southwest would be considered a northeast wind because winds are named for the direction of their origin. However velocity vectors point in the direction of travel).

Types of vectors: Vectors are the physical quantities having magnitudes as well as specified directions, e.g. velocity, displacement, acceleration, force, etc. these quantities require special laws for addition, subtraction and multiplication. There are different types of vectors, for example,

Sl. No.	Types	Description
1.	Polar vectors	The vectors having a fixed point of start or a point of application are known as polar vectors, e.g. displacement, velocity, acceleration and force.
2.	Axial vector	The vectors acting along the axis of rational effect of other vectors are known as axial vectors, e.g. angular velocity, angular momentum, torque, etc.
3.	Coincidental vectors	The vectors having same starting point are called coincidental or co-initial vectors or concurrent vectors.
4.	Collinear vectors	The vectors acting on same line are called collinear vectors and in parallel are called parallel vectors.
5.	Coplanar vector	The vector acting in the same plane are called coplanar vectors.
6.	Negative vector	A negative vector is a vector of equal magnitude but opposite direction.

SCALAR MOTION

Scalars of the same kind are added, subtracted, multiplied or divided by using the ordinary rules of arithmetic. In other words, a scalar has only magnitude and no direction. Example of scalar are: mass, distance, speed, energy, work, kinetic, power, etc.

Definition

1. Scalers are the physical quantities having magnitude only, e.g. speed, path length, i.e. distance work, energy, pressure, etc.
2. A scalar is a quantity that can be completely specified by its magnitude with appropriate units.

Scalar quantities: Most of the physical quantities encountered in physics are either scalar or vector quantities. A scalar quantity is defined as a quantity that has magnitude only. Typical examples of scalar quantities are time, speed, temperature, and volume. A scalar quantity or parameter has no directional component, only magnitude. For example, the units for time (minutes, days, hours, etc.) represent an amount of time only and tell nothing of direction. Additional examples of scalar quantities are density, mass, and energy. A vector quantity is defined as a quantity that has both magnitude and direction. To work with vector quantities, one must know the method for representing these quantities.

Magnitude, or "size" of a vector, is also referred to as the vector's "displacement." It can be thought of as the scalar portion of the vector and is represented by the length of the vector. By definition, a vector has both magnitude and direction. Direction indicates how the vector is oriented relative to some reference axis, as shown in Figure 1. Using north/south and east/west reference axes, vector "A" is oriented in the NE quadrant with a direction of 45 north of the o EW axis. Giving direction to scalar "A" makes it a vector. The length of "A" is representative of its magnitude or displacement.

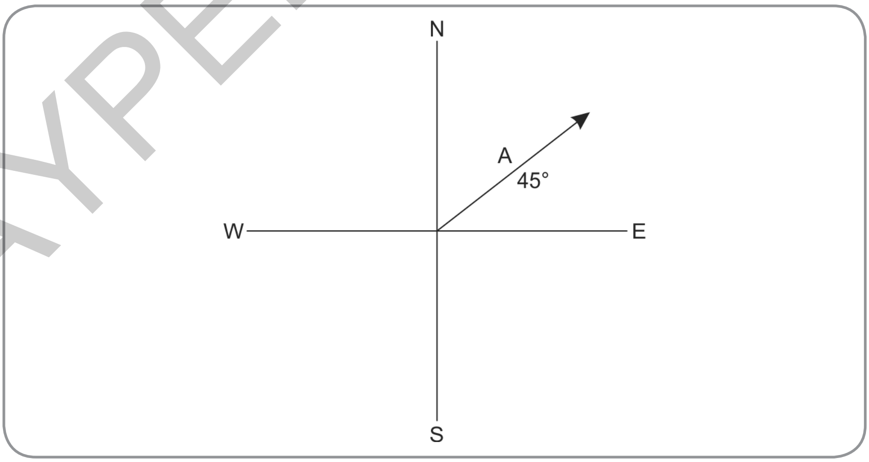

Fig. 3.2: Scalar motion

SPEED

Speed of a body is the time rate of change of position, without reference to a particular direction. Speed is a scalar quantity.

Speed = distance traveled/time taken

Definition

The speed v is defined as the magnitude of the velocity v, which is the derivative of the position r with respect to time:

$$v = |\mathrm{v}| = |\dot{r}| = \left|\frac{dr}{dt}\right|$$

If s is the length of the path traveled until time t, the speed equals the time derivative of s:

$$v = \frac{ds}{dt}$$

In the special case where the velocity is constant (that is, constant speed in a straight line) this can be simplified to $v = s/t$. The average speed over a finite time interval is the total distance traveled divided by the time duration.

Expressed in graphical language, the slope of a tangent line of a distance-time graph is the instantaneous speed, and the slope of a chord line of distance-time graph is the average speed over the time interval between the ends of the chord. The SI unit of speed is ms^{-1} and the dimensional formula is [L′M°r′], Symbol u or v.

Note: Speed can be zero or positive, but can never be negative.

1. **Uniform speed:** Speed is said to be uniform if the body travels equal distances in equal intervals of time, however small these intervals may be. For example, A car moves from Bangalore to Mysore (150 km) in 3 hours. Speed = 150 km 13 hours or 50 km 1 hour. If the car covers 50 km in every hour, 25 km in every ½ hour (30 mm) i.e. 5 km in every 6 mm, etc. throughout its journey, then the speed is uniform.
2. **Variable speed:** Speed is said to be variable or non-uniform, if the body travels unequal distances in equal intervals of time. For example, In the above example, if the car covers 60 km in 1 St hour, 40 km in the 2nd hour and 50 km in the 3rd hour of the journey, then the speed is variable.
3. **Average speed:** When the body has variable speed, average speed is that constant speed with which the body should travel, to cover the same total distance in the same total time as it does with variable speed. Average speed is defined as the ratio of the total distance traveled to the total time taken.
4. **Instantaneous speed:** For a body having variable speed, the instantaneous speed is the ratio of distance traveled to the time taken, over a very small interval of time. This gives the value of speed at any instant ‘t’. For example, for a car moving with variable speed, the speedometer shows the instantaneous speed.

ACCELERATION

It is a common observation that body’s fall towards the ground. A stone thrown upward will reach the ground. This is due to the gravitational force of attraction offered by the earth.

Acceleration change in velocity/time taken acceleration is a vector quantity. It is positive if the velocity is increasing with time (v > u) and is negative if the velocity is decreasing (v < u). The negative acceleration is also called retardation or deceleration.

Acceleration is a form of motion where the object's velocity changes. It is most commonly measured in m/s/s. The formal definition for acceleration would be the rate of change of velocity with respect to time.

Explanation: Motion is a natural event that involves a change in the position or location of an object. Motion can be in the form of acceleration, deceleration, or a constant speed. This can be compared to a vehicle. A vehicle may accelerate as you press down on the gas pedal, or as it rolls down a hill. The car decelerates when you step on the brake pedal. To find acceleration you would use one of these formulae.

Definition: The rate at which the velocity of an object changes, that is the change in velocity per unit time, is called the acceleration of the object.

Any change in the velocity of an object results in an acceleration: Increasing speed (what people usually mean when they say acceleration), decreasing speed (also called deceleration or retardation), or changing direction. Yes, that's right, a change in the direction of motion results in an acceleration even if the moving object neither sped up nor slowed down. That's because acceleration depends on the change in velocity and velocity is a vector quantity—one with both magnitude and direction. Thus, a falling apple accelerates, a car stopping at a traffic light accelerates, and an orbiting planet accelerates. Acceleration occurs anytime an object's speed increases, decreases, or changes direction.

Much like velocity, there are two kinds of acceleration: average and instantaneous. Average acceleration is determined over a "long" time interval. The word long in this context means finite—something with a beginning and an end. The velocity at the beginning of this interval is called the initial velocity (**v**) and the velocity at the end is called the final velocity ($\mathbf{v}_0$) [v nought].

Uniform or constant acceleration: Acceleration of a body is said to be uniform if the velocity of the body changes b3 equal amounts in equal time intervals, however small the intervals may be. Otherwise, the acceleration is said to be variable. For example, a body falling freely has uniform acceleration due to gravity.

Note:

1. If the acceleration is parallel to that of velocity, then only the magnitude of velocity changes. If 'a' is in the direction of 'v', the magnitude of 'v' increases, i.e. 'a' is positive. For example, a stone falling freely under gravity. If the direction is opposite to that of 'v', the magnitude of 'v' decreases, i.e. 'a' is negative. For example, a stone thrown vertically upwards.
2. If the acceleration is not parallel to that of velocity, the direction of velocity also changes, i.e. the body takes a turn.

VELOCITY

Velocity of moving body is the rate of change of displacement of the body in a particular direction. Velocity = displacement/time.

Definition

1. Velocity is a vector quantity; it is a rate of change of motion in a specified direction.

2. Displacement (s) is defined as the shortest distance between the initial and the final positions of the body. The rate of change of position of a body is called speed. Speed in a particular direction is called velocity.
3. The velocity of a body is the distance traveled by the body in a specified direction in a unit of time interval.

Types of Velocity

1. **Uniform velocity:** When body covers equal distance, in equal intervals of time in a specified direction, however short the time intervals may be, the body is said to be moving with a uniform velocity. (a) It covers equal distances in equal intervals to time, i.e. the magnitude does not change. (b) Its direction remains same.
2. **Variable velocity:** When a body covers unequal distance in equal intervals of time in a specified direction or equal distances in equal intervals of time, but its direction changes, then the body is said to be moving with variable velocity.
3. **Average velocity:** The displacement of a body per unit time, when body is actually moving with variable velocity, is called average velocity. Average velocity = total displacement/total time.
4. **Instantaneous velocity:** The velocity of an object at a particular instant of time or at a particular point of its path is called instantaneous velocity of the object.

NURSING APPLICATION OF VELOCITY

Sl. No.	Concept	Description
1.	Momentum	Momentum is useful in exercise, or it may have undesirable effects. When part of a body is moving with appreciable momentum, it tends to go on moving and very little muscle action is necessary to maintain the movement. This may be advantage, to increase the range of movement, on exercise point of view this is disadvantage.
2.	Centrifuge	1. Theodor Svedberg invented the centrifuge in 1925, for which he was awarded noble prize in chemistry in the year 1926. 2. It is equipment that makes a substance in circular motion. 3. Generally it has a cylindrical vessel capable of rotating at high speed by an electronic motor that drives the sample in rotatory motion. 4. This motion is used to offer centrifugal force, which separate a fluid from a fluid or from a solid. 5. It also used to separate heavier particles in, the heavier particles move away from the axis of rotation and the lighter particles move near to the axis of rotation.

DIALYSIS

A properly functioning kidney helps prevent salt, extra water, and waste from accumulating in the body. It also helps control blood pressure and regulates important chemicals in the blood, such as sodium (salt) and potassium. When the kidneys do not perform these functions due to disease or injury, dialysis can help purify the blood and remove waste. The length of treatment depends on the patient's size, the levels of waste in their body, and whether hemodialysis or peritoneal dialysis is used. Typical hemodialysis treatments last about four hours and are needed about three times a week. Peritoneal dialysis can be done at home, at work, or during sleep, depending on the style of treatment your doctor recommends.

There are two different types of dialysis.

1. **Hemodialysis** involves using an artificial kidney, known as a hemodialyzer, to remove waste and chemicals from the blood. It accesses the blood through a minor surgical procedure in the arm or leg, or through a plastic tube in the neck called a catheter.

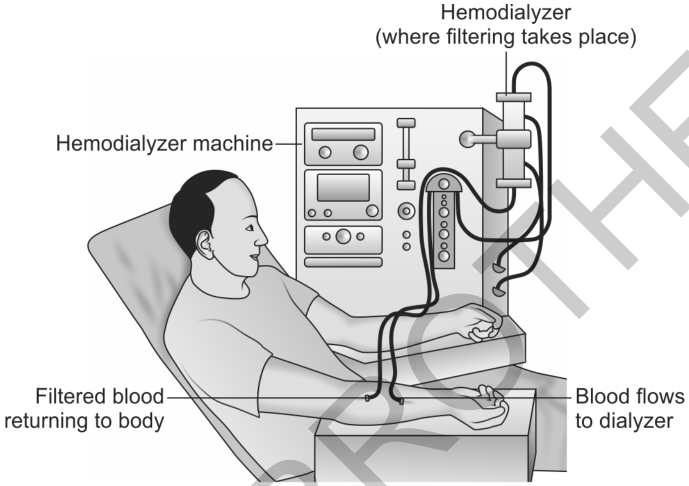

Fig. 3.3: Hemodialysis procedure

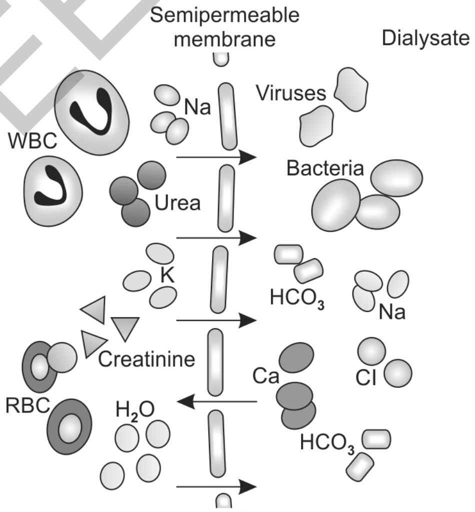

Fig. 3.4: Principles of dialysis

2. **Peritoneal dialysis** involves the surgical implantation of a catheter into your stomach area. During treatment, a special fluid called dialysate is pumped into the abdomen where it draws waste out of the bloodstream.

Principles of dialysis: Principles of dialysis are accomplished through both ultrafiltration and diffusion ultrafiltration refers to the removal of fluid from the body by the use of either osmotic or hydrostatic pressure to produce the necessary gradient. Diffusion which is the passage of particles from an area of high concentration to an area of low concentration both processes occur across a semipermeable membrane, one with large pores enough to allow certain particles to pass through but too small to allow the passage of larger particles.

When the two solutions are separated by a semipermeable membrane, solute particles will move toward the solution with lesser concentration simultaneously.

HEMODIALYSIS

Dialysis was first used to treat human patients in 1945-replaces or supplements the action of the kidneys in a person suffering from acute or chronic renal failure or from poisoning by diffusible substances, such as aspirin, bromides, or barbiturates. Blood is diverted from an artery, usually one in the wrist, into the dialyzer, where it flows-either by its own impetus or with the aid of a mechanical pump-along one surface of the membrane. Finally the blood passes through a trap that removes clots and bubbles and returns to a vein in the patient's forearm. In persons with chronic kidney failure, who require frequent dialysis, repeated surgical access to the blood vessels used in the treatments is obviated by provision of an external plastic shunt between them.

Dialysis**,** also called hemodialysis, renal dialysis, or kidney dialysis, in medicine, the process of removing blood from a patient whose kidney functioning is faulty,

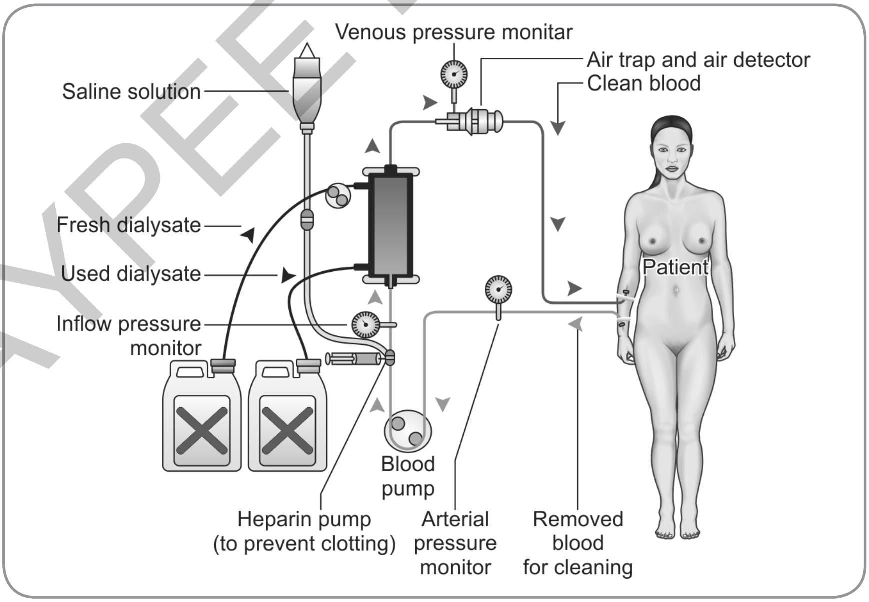

Fig. 3.5: Hemodialysis system

purifying that blood by dialysis, and returning it to the patient's blood stream. The artificial kidney, or hemodialyzer, is a machine that provides a means for removing certain undesirable substances from the blood or of adding needed components to it. By these processes the apparatus can control the acid–base balance of the blood and its content of water and dissolved materials. Another known function of the natural kidney-secretion of hormones that influence the blood pressure-cannot be duplicated. Modern dialyzers rely on two physicochemical principles, dialysis and ultrafiltration.

Dialysis is the most common treatment for kidney failure. A dialysis machine is an artificial kidney designed to remove impurities from your blood. During dialysis, physicians use the dialysis access to remove a portion of your blood to circulate it through the dialysis machine so it can remove impurities and regulate fluid and chemical balances.

Definition

It is defined as the life saving procedure in which the toxic waste, removed from the blood through purifying dialyzer and the purified blood return back to the body through arteriovenous fistula.

Indications

1. Patient with acute reversible renal failure.
2. For regular long-term treatment of patient with chronic end- stage-renal disease.
3. Acute poisoning such as barbiturate or analgesic overdose.

Equipment

Preparation of Hemodialysis Machine

1. Hemodialysis with appropriate dialyzer
2. IV solution, administration set, lines, IV pole
3. Dialysate
4. Injection heparin, 3 mL syringe with needle, medication label, hemostats.

Preparation of Double Lumen Catheter for Dialysis

1. Povidone iodine sponges.
2. Two sterile 4" × 4' gauze pads.
3. Two 3 mL and two 5 mL syringes.
4. Tape.
5. Injection heparin bolus syringe.
6. Clean gloves.

Preparation for AV Fistula for Dialysis

1. Two winged fistula needles (each attached to 10 mL syringe filled with heparin flush solution)
2. Linen-saver pad
3. Povidone iodine sponges.
4. Sterile 4' × 4" gauze pads
5. Tourniquet
6. Clean gloves
7. Adhesive tapes.

Essentials of Biophysics in NURSING

Salient Features

- As per revised Indian Nursing Council (INC) curriculum
- Systematically organized according to the syllabus
- User-friendly and easy-to-follow text
- Useful for both student as well as teacher
- Helps to perform the examination confidently
- Simple and lucid language illustrated with simple diagrams and tables.

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